METHOD OF AND APPARATUS FOR OFFSHORE MOORING

TECHNICAL FIELD

This invention relates generally to the mooring of mobile offshore drilling units, floating production platforms, SPARs, and other vessels at offshore venues, and more particularly to a method of and apparatus for mooring at offshore venues which does not require the use of winches, fair leads, stoppers, or other appurtenances on the vessel being moored and which obviates the need for dynamic positioning systems in the offshore mooring of vessels.

BACKGROUND AND SUMMARY OF THE INVENTION

Mobile offshore drilling units (MODUs), floating production platforms (FPPs), SPARs, and similar vessels are often moored at offshore venues utilizing either preset catenary mooring lines or preset taut-leg mooring lines. Mooring is accomplished by first attaching a plurality of preset mooring lines to the vessel to be moored, and thereafter applying a predetermined tension to each of the mooring lines. Heretofore the necessary tension has been applied to the mooring lines utilizing winches mounted on the vessel to be moored.

Winches having sufficient capacity to be used in tensioning mooring lines of the type used in offshore mooring operations are exceedingly expensive, but are used only intermittently, such as during the initial mooring of the vessel upon which they are installed, during relocation of the vessel, and in response to changing conditions at the mooring site. Thus, a need exists for method of and apparatus for mooring MODUs, FPPs, SPARs, and similar vessels at offshore venues which does not require the installation of mooring winches on the vessel to be moored.

Offshore mooring can also be accomplished using a technique known as dynamic positioning. The dynamic positioning technique involves the use of one or more propulsion devices mounted on the vessel to be moored which

are operated to maintain the vessel at a specified location as determined by GPS technology. Although generally satisfactory in operation, dynamic positioning systems require the consumption of substantial amounts of fuel and are therefore expensive to operate. The fuel consumption necessary in the operation of dynamic positioning systems also raises environmental concerns.

The present invention comprises a method of and apparatus for offshore mooring which fulfills the foregoing and other requirements long since found lacking in the prior art. In accordance with a first embodiment of the apparatus of the invention, a clamping apparatus is provided at the distal end of either a preset catenary mooring line or a preset taut-leg mooring line. A wire or chain pendant extends from the vessel to be moored through the clamping apparatus. The distal end of the pendant is connected to a line which extends to a winch mounted on an anchor handling vessel. The winch is utilized to pull the pendant through the clamping apparatus until a predetermined tension is exerted on the mooring line and the pendant. The clamping apparatus is then actuated to securely clamp the pendant to the mooring line while maintaining the predetermined tension. In this matter the tension necessary to properly moor the vessel at the

offshore site is achieved without requiring the use of mooring winches on the vessel being moored.

In accordance with more specific aspects of the invention, a remotely operated vehicle (ROV) is deployed from the anchor handling vessel. A chain is mounted at the distal end of the pendant, and a submersible buoy is mounted at the distal end of the chain. The line deployed from the winch on the anchor handling vessel is secured to the pendant during tensioning operations.

The chain portion of the pendant extends around a pulley or sheave mounted on the clamping apparatus. When the predetermined tension has been applied to the mooring line and the pendant by the winch on the anchor handling vessel, the ROV actuates the clamping apparatus to securely clamp the pendant to the mooring line while maintaining the predetermined tension. Thereafter, the ROV disengages the vessel from the pendant.

In accordance with a first embodiment of the method of the invention, a clamping apparatus is mounted at the distal end of a preset mooring line. The clamping apparatus is brought on board an anchor handling vessel. A pendant extending from a vessel to be moored is directed through the clamping apparatus and is secured to a line extending from a winch mounted on the anchor handling vessel. The clamping apparatus having the pendant

extending therethrough is then lowered into the sea, and the winch on the anchor handling vessel is operated to apply increasing tension to the pendant and the mooring line until a predetermined tension is achieved. An ROV deployed from the anchor handling vessel is then utilized to actuate the clamping apparatus to securely clamp the pendant into engagement with the mooring line while maintaining the predetermined tension, and thereafter to disengage the pendant from the anchor handling vessel.

BRIEF DESCRIPTION OF THE DRAWINGS

A more completely understanding of the invention may be had by reference to the following Detailed Description when taken in conjunction with the accompanying Drawings, wherein:

FIGURE 1 is a diagrammatic illustration of an apparatus for offshore mooring comprising a first embodiment of the invention;

FIGURE 2 is an illustration similar to FIGURE 1 showing the apparatus thereof at the completion of a mooring installation;

FIGURE 3 is an enlargement of a portion of FIGURE 1;

FIGURE 4 is a sectional view taken along the line 44 in FIGURE 3 in the direction of the arrows;

FIGURE 5 is a transverse sectional view taken through the apparatus of FIGURE 3 and further illustrating the clamping mechanism thereof;

FIGURE 6 is an illustration similar to FIGURE 3 illustrating a clamping mechanism comprising a stopper arm;

FIGURE 6A is a view similar to FIGURE 6 illustrating a variation of the mechanism shown therein;

FIGURE 7 is a diagrammatic illustration of a early steps in the method comprising the first embodiment of the invention;

FIGURE 8 is a diagrammatic illustration of a later step in the method of FIGURE 7;

FIGURE 9 is a diagrammatic illustration of a later step in the method of FIGURES 7 and 8;

FIGURE 10 is a diagrammatic illustration of a later step in the method of FIGURES 7, 8, and 9;

FIGURE 11 is a diagrammatic illustration of a later step of the method illustrated in FIGURE 7, 8, 9, and 10;

FIGURE 12 is an illustration of a later step in the method of the invention illustrated in FIGURES 7, 8, 9, 10, and 11;

FIGURE 13 is an illustration of a later step in the method illustrated in FIGURES 7, 8, 9, 10, 11, and 12;

FIGURE 14 is a diagrammatic illustration of a later step in the method illustrated in FIGURES 7, 8, 9, 10, 11, 12, and 13;

FIGURE 15 is a diagrammatic illustration of the concluding steps of the method illustrated in FIGURES 7 through 14, inclusive;

FIGURE 16 is a diagrammatic illustration of a method of and apparatus for offshore mooring comprising a second embodiment of the invention;

FIGURE 17 is a side view illustrating an apparatus for offshore mooring comprising a third embodiment of the invention;

FIGURE 18 is a perspective view further illustrating the apparatus of FIGURE 17;

FIGURE 19 is a perspective view similar to FIGURE 18 in which certain parts have been broken away more clearly to illustrate certain features of the invention;

FIGURE 20 is a perspective view further illustrating the apparatus of FIGURE 17;

FIGURE 21 is a diagrammatic illustration of early steps in a method of offshore mooring comprising a fourth embodiment of the invention;

FIGURE 22 is a diagrammatic illustration of a later step in the method of FIGURE 21;

FIGURE 23 is a diagrammatic illustration of a later step in the method of FIGURES 21 and 22;

FIGURE 24 is a diagrammatic illustration of a later step in the method of FIGURES 21 through 23, inclusive;

FIGURE 25 is a diagrammatic illustration of a later step in the method of FIGURES 21 through 24, inclusive;

FIGURE 26 is a diagrammatic illustration of a later step in the method of FIGURES 21 through 25, inclusive;

FIGURE 27 is a diagrammatic illustration of a later step in the method of FIGURES 21 through 26, inclusive;

FIGURE 28 is a diagrammatic illustration of a later step in the method of FIGURES 21 through 27, inclusive;

FIGURE 29 is a diagrammatic illustration of a later step in the method of FIGURES 21 through 28, inclusive;

FIGURE 30 is a diagrammatic illustration of a later step in the method of FIGURES 21 through 29, inclusive;

FIGURE 31 is a diagrammatic illustration of a mooring installation constructed in accordance with the method of FIGURES 21 through 30, inclusive;

FIGURE 32 is a diagrammatic illustration of a method of offshore mooring comprising a fifth embodiment of the invention; and

FIGURE 33 is a diagrammatic illustration of a method of offshore mooring comprising a sixth embodiment of the invention.

DETAILED DESCRIPTION

Referring now the Drawings, and particularly to Figures 1 through 6 thereof, there is shown method of and apparatus for offshore mooring 20 comprising a first embodiment of the invention. In accordance with the invention, a vessel to be moored (VTBM) 22 is located at an offshore venue. The VTBM may comprise a mobile offshore drilling unit, a floating production platform (monohull or semisubmersible), a SPAR, or any other vessel requiring offshore mooring. A plurality of wire or chain mooring attachment pendants 24 are secured to the VTBM at spaced apart locations around the circumference thereof. Each mooring attachment pendant 24 is secured to the VTBM through a padeye 26. Each padeye 26 is provided with a tension measuring device such as a strain gauge. The function of the tension measuring device is to produce an output indicative of the tension applied to its associated padeye 26 by the mooring attachment pendant 24 secured thereto.

The apparatus for offshore mooring 20 further includes a plurality of mooring lines 30. As will be appreciated by those skilled in the art, each mooring line 30 comprises multiple components, including wire, chain, connectors, etc. The major part of each mooring line 30 is installed before the VTBM is on site; therefore, the mooring lines

30 are referred to as preset mooring lines. Each preset mooring line 30 extends from an anchor 32 which is securely engaged with the sea floor 34. The preset mooring lines 30 may be secured to the sea floor by drag embedment anchors, vertically loaded anchors, driven piles, suction anchors, suction embedded plate anchors, or other anchor types suitable for offshore mooring.

As will be appreciated by those skilled in the art, the preset mooring lines 30 may comprise either catenary preset mooring lines or taut-leg preset mooring lines. The mooring lines 30 are equal in number to the number of mooring attachment pendants 24 secured to the VTBM, and are positioned around the site at which the VTBM is to be moored in a more or less circular array.

In accordance with the first embodiment of the invention, each preset mooring line 30 has a clamping apparatus 40 secured to the distal end thereof. Referring particularly to Figures 3 and 4, each clamping apparatus 40 comprises a box shaped frame 41 having a padeye 42 mounted at one end thereof. The padeye 42 is utilized to secure the clamping apparatus 40 to its associated preset mooring line 30.

The clamping apparatus 40 includes a slotted sheave or pulley 43 which is rotatably supported on the frame 40 by suitable bearings 44. The sheave 43 includes a wide

outer slot and a narrow inner slot. The clamping apparatus 40 further includes a clamping mechanism 46 mounted at the opposite end of the frame 42 from the padeye 42.

As is best shown in Figure 3, the clamping mechanism 46 may comprise a chain stopper 47 which is slidedly supported in the frame 41 of the clamping apparatus 40 for movement in the direction of the arrows 48. A threaded member 49 is threadedly engaged with the frame 42. Therefore, upon rotation of the threaded member 49, the chain stopper 47 is selectively positioned relative to the frame 41. The threaded member 49 extends to a socket 50 which adapted for actuation by a remote operated vehicle (ROV).

Referring to Figure 6, there is shown an alternative clamping mechanism 52 which may be incorporated in the clamping apparatus 40 in lieu of the clamping mechanism 46 shown in Figures 3 and 5. The clamping mechanism 52 comprises a stopper arm 54 which is pivotally supported on the frame 41 of the clamping apparatus 40 by a cylindrical member 56. The stopper arm 54 is spring biased to pivot in the direction indicated by the arrow 58. An arm 60 is secured to the stopper arm 54 and extends out of the frame 41 of the clamping apparatus 40 for actuation by a remote operated vehicle to selectively pivot the stopper arm 54 in the direction opposite of the arrow 58.

As is shown in Figure 6, the stopper arm normally prevents a chain extending through the clamping apparatus 40 and around the slotted sheave 43 thereof for moving rightwardly (Figure 6). However, the chain is free to move in the leftward direction (Figure 6) because the stopper arm 54 simply pivots upwardly against the action of its spring bias until sufficient leftward movement has occurred for the stopper arm 54 to engage the next link of the chain. Whenever the remote operated vehicle is utilized to actuate the arm 60 to pivot the stopper arm 54 in the direction opposite that of the arrow 58, the chain is allowed to move freely in the rightward direction (Figure 6).

Referring to Figure 6A, there is shown a clamping apparatus 40' which may be used in lieu of the clamping apparatus 40 of Figure 6. Many of the component parts of the clamping apparatus 40' are substantially identical to component parts comprising the clamping apparatus 40 as illustrated in Figure 6 and described hereandabove in conjunction therewith. Such identical component parts are designated in Figure 6A which are the same reference numerals utilized in Figure 6 but are differentiated therefrom by means of a prime (') designation.

The clamping apparatus 40A differs from the clamping apparatus 40 in that it is provided with a guide roller 61

which guides the chain through the clamping mechanism 52' and into the slotted pulley 43'. This assures that the chain will be properly oriented relative to the component parts of the clamping mechanism 52' regardless of the angular orientation of the chain relative to the angular orientation of the mooring line.

Referring again to Figure 1, each mooring attachment pendant 24 may have one or more adjustment pendants 64 secured thereto depending upon the length of the associated preset mooring line 30 and the depth of the ocean at the venue comprising the location of the VTBM 22. A chain 66 is secured to the distal end of the mooring attachment pendant 24 and any adjustment pendants connected thereto. The mooring attachment pendant 24, any adjustment pendants 64 connected thereto, and the chain 66 comprise a pendant 67 which is broadly defined to include all of the components connected between the padeye 26 of the VTBM 22 and the clamping apparatus 40.

The chain 66 extends through the clamping mechanism of the clamping apparatus 40 and around the pulley 43 thereof. A submersible buoy 68 is secured to the distal end of the chain 66.

The apparatus for offshore mooring 20 further including a large anchor handling vessel 80. The vessel 80 is provided with a winch 82. A line 84 extends from the

winch 82 and is secured to the pendant 67. As is indicated by the arrows 86, the winch 82 of the vessel 80 is utilized to apply an upwardly directed force of the distal end of the chain 66 thereby applying increasing tension to the pendant 67 and to the preset mooring line 30.

The vessel 80 also deploys an ROV 90. After the winch 82 of the vessel 80 has applied the predetermined tension to the pendant 67 and to the preset mooring line 30, the ROV 90 actuates the clamping mechanism of the clamping apparatus 40 to move the either chain stopper 47, or the stopper arm 54, or the stopper arm 54' into engagement with the chain 66. In this manner the pendant 67 is securely clamped to the preset mooring line while maintaining the predetermined tension throughout the entire connection between the VTBM 22 and the anchor 32. After the clamping mechanism has been actuated to securely clamp the pendant 47 into engagement with the mooring line 30, the ROV 90 disengages the line 84 from the submersible buoy 68.

The configuration of each of the mooring lines 30, the clamping apparatus 40 connected thereto, and the associated pendant 67 at the conclusion of mooring operations is illustrated in Figure 2. The distal end of the chain 66 is maintained in a vertical orientation by the submersible buoy 68. This allows re-engagement of the pendant 67 by a line extending from an anchor handling vessel in the

event that an adjustment in the tension that is applied to the VTBM by one or more of the mooring lines attached thereto is required.

As will be appreciated by those skilled in the art, proper mooring of the VTBM 22 typically requires a plurality of pendants and associated preset mooring lines. Mooring of the VTBM 22 is accomplished by actuating the chain 66 comprising each of the pendants to apply the required tension thereto. After tension has been applied to all of the pendants extending from a particular VTBM, further adjustments in the tensioning of particular pendants may be required. After all of the pendants and the associated preset mooring lines connected to the VTBM have been properly tensioned, the vessel 80 departs and the VTBM 22 remains securely moored.

A more complete understanding of the method of offshore mooring 20 comprising the present invention may be had by reference to Figures 7 through 15, inclusive. A plurality of preset mooring lines 30 are installed at spaced apart locations around a mooring venue. Each preset mooring line 30 includes an anchor 32 which is securely engaged with the sea floor 34, and extends from the anchor 32 along the surface of the sea floor 34 to a clamping apparatus 40. A recovery pendant 92 is initially secured

to the clamping apparatus 40 and is maintained in a vertical orientation by a submersible buoy 94.

A vessel 80 is maneuvered above the location of the clamping apparatus 40. A line 96 is extended downwardly from the vessel 80 as indicated by the arrows 98. An ROV 90 is deployed from the vehicle 80 and is utilized to secure the line 96 into engagement with the recovery pendant 92.

Referring to Figures 8 and 9, the line 96 is utilized to bring the clamping apparatus 40 on board the vessel 80. A line 102 is secured to the clamping apparatus 40. The line 102 is paid out in the manner indicated by the arrows 104 as the vessel 80 moves toward a VTBM 22 as indicated by the arrow 106.

As is shown in Figure 10, the vessel 80 continues to move toward the VTBM 22 in the direction indicated by the arrow 106. Meanwhile, the line 102 continues to pay out. A crane 108 mounted on the VTBM 22 passes a mooring attachment pendant 24 associated with the mooring line 30 to the vessel 80.

Referring to Figure 11, the vessel 80 next moves away from the VTBM 22 as indicated by the arrow 110. Adjustment pendants 64 are connected to the mooring pendant 24 as needed and are paid out as indicated by the arrow 112. The line 102 is drawn on board the vessel 80 as indicated by

the arrows 114, thereby moving the clamping apparatus 40 upwardly.

As is shown in Figure 12, a chain 66 is connected to the distal end of the pendant 24, it being understood that one or more adjustment pendants 64 may be connected between the chain 66 and the pendant 24. The chain 66 is paid out from the vessel 80 as indicated by the arrow 116.

Referring to Figures 13 and 14, the clamping apparatus 40 is brought on board the vessel 80. A line 118 is extended through the clamping apparatus 40 while the clamping apparatus 40 is on board the vessel 80. The distal end of a line 118 is in turn connected to a line 122 extending from a winch on board the vessel 80. A line 124 is connected to the clamping apparatus 40 and is utilized to lower the clamping apparatus as indicated by the arrows 126.

Lowering of the clamping apparatus 40 continues until the chain 66 passes through the clamping apparatus 40. At this point the lines 122 and 124 are recovered onto the vessel 80 until the clamping apparatus 40 and the chain 66 extending therethrough are either adjacent to or on board the vessel 80. A submersible buoy 68 is then inserted at the distal end of the chain 66. The lines 122 and 124 are then paid out until the clamping apparatus 40 and the chain 66 are positioned as shown in Figure 11.

The ROV 80 is then employed to disengage the line 124 from the clamping apparatus 40. The line 124 is recovered on board the vessel 80 as indicated by the arrow 130. The winch 82 on board the vessel 80 applies an upwardly directed force to the chain 66 as indicated by the arrow 132. When the predetermined tension has been applied to the pendant and the preset mooring line, the ROV 80 is utilized to actuate the clamping apparatus 40 to securely clamp the pendant to the preset mooring line while maintaining the predetermined tension thereon. The ROV 80 is thereafter utilized to disengage the line 122 from the chain 66.

Referring to Figure 16, there is shown a method of and apparatus for offshore mooring 150 comprising a second embodiment of the invention. In accordance with the second embodiment of the invention, a pendant 152 extends from a vessel to be moored (VTBM) 153 and is secured to a clamping apparatus 154. The pendant 152 is substantially identical to the pendant 67 illustrated in Figures 1 through 15, inclusive, and described hereandabove in conjunction therewith, except that the pendant 152 does not necessarily have a chain secured at its distal end. The clamping apparatus 154 is substantially identical in construction and function to the clamping apparatus 40 as illustrated in Figures 3 through 6, inclusive, and includes a clamping

mechanism such as the clamping mechanism 46 shown in Figures 3 and 5, or the clamping mechanism 52 shown in Figure 6, or the clamping mechanism 52' of Figure 6A.

A mooring line 156 extends from a suitable anchor (not shown in Figure 16). The mooring line 156 is substantially identical in construction and function to the mooring line 30 as illustrated in Figures 1 through 15, inclusive, except that the mooring line 156 has a chain 158 secured to the distal end thereof. A submersible buoy 160 is secured to the distal end of the chain 158.

As will be appreciated by those skilled in the art, the deployment and function of the method of and apparatus for offshore mooring 150 comprising the second embodiment of the invention are substantially identical to the deployment and operation of the method of and apparatus for offshore mooring 20 comprising the first embodiment of the invention. The first and second embodiments of the invention differ primarily in the fact that the clamping apparatus 154 of the second embodiment of the invention is secured to the pendant 152 as opposed to being secured to the mooring line. This in turn causes the tensioning force to be applied by an anchor handling vessel to a chain secured at the distal end of the mooring line and extending through the clamping mechanism and around the slotted sheave of the clamping apparatus 154.

Referring to Figures 17 through 20, inclusive, there is shown an apparatus for offshore mooring 190 comprising a third embodiment of the invention. The apparatus 190 comprises a pin 192. The remaining components of the apparatus 190 are rotatably and/or pivotally supported on the pin 192. The apparatus 190 further includes a slotted pulley or sheave 194 which is rotatably supported on the pivot pin 192. The slotted pulley 194 includes an inner narrow slot 196 which receives the nominally vertically oriented links of a chain 198, and an outer wide slot 200 which receives the nominally horizontally oriented links of the chain 198.

The apparatus for offshore mooring 190 further includes an attachment arm 202 which is pivotally supported on the pin 192. A shackle 204 is mounted at one end of the attachment arm 202, and a shackle 206 is mounted at the opposite end thereof. The shackle 204 is utilized whenever it is necessary to raise or lower the apparatus for offshore mooring 190 relative to an anchor handling vessel. In such instances a line extending from the anchor handling vessel is secured to the shackle 204 of the apparatus 190 by a remote operated vehicle.

The shackle 206 has a chain 208 connected thereto. When the apparatus for offshore mooring 190 is utilized in conjunction with the method for offshore mooring

illustrated in Figures 1 through 15, inclusive, and described hereinabove in conjunction therewith, the chain 208 comprises the distal end of the mooring line 30 and the chain 198 comprises the distal end of the pendant 67. In the case of the method of offshore mooring illustrated in Figure 14 and described hereinabove in conjunction therewith the chain 208 comprises the distal end of the pendant 152 and the chain 198 comprises the distal end of the mooring line 156.

The apparatus for offshore mooring 190 further comprises a clamping apparatus 210 which is pivotally supported on the pin 192. Referring particularly to Figure 19, the clamping apparatus 210 includes a rectangular chain guiding aperture 212 which receives the chain 198 therethrough. The aperture 212 extends to a guide plate 214 having a slot 216 formed therein which receives the nominally vertically oriented links of the chain 198.

The clamping apparatus 210 further includes a clamping mechanism 220. Referring momentarily to Figure 17, the clamping mechanism 220 includes a stopper arm 222 which is pivotally supported for movement between the full line position and the dashed line position as shown in Figure 17. Referring to Figure 19, the stopper arm 222 has a curved chain engaging plate 224 mounted at the distal end thereof which normally engages one of the nominally

vertically oriented links of the chain 198 to prevent movement of the chain 198 in the direction of the arrow 226 (Figure 19).

Referring to Figures 18 and 19, the clamping apparatus 210 comprises spaced parallel plates 230 extending on opposite sides of the slotted pulley 194. The plates 230 are interconnected by a reinforcing member 232 and by reinforcing members 234 which are mounted on the underside of the guide plate 214. An aperture 236 extends through one of the guide plates 230, it being understood that both guide plates 230 may be provided with apertures 236, if desired. The aperture 236 provides access to the stopper arm 222 by a tool mounted on a remote operated vehicle, thereby permitting the remote operated vehicle to selectively pivot stopper arm 222 from the position shown in full lines in Figure 17 to the position shown in dashed lines therein. In this manner the stopper arm 222 is disengaged from the chain 198 thereby allowing the chain 198 to move in the direction of the arrow 226 (Figure 19). As will be appreciated by those skilled in the art, the stopper arm 222 is normally retained in the position of the full lines in Figure 17 by a suitable spring.

A method of offshore mooring 250 comprises a fourth embodiment of the invention as illustrated in Figures 21 through 31, inclusive. Referring first to Figure 21, a

vessel to be moored (VTBM) 252 is located at an offshore mooring site. Although the VTBM illustrated in Figures 21 through 31 is a mobile offshore drilling unit, the method of offshore mooring 250 is equally adapted to the mooring of floating production platforms, SPARs, as well as other vessels requiring offshore mooring. The VTBM 252 has a plurality of connection pendants 254 secured thereto.

A mooring line 260 includes a ground chain 262 which is secured to an anchor 264. The anchor 264 is securely engaged with the sea floor 266 and may comprise a drag embedment anchor, a vertically loaded anchor, a driven pile, a suction anchor, a suction embedded plate anchor, or any other anchor type adapted for mooring in deep waters. A submersible buoy 268 is connected to the distal end of the mooring line 260.

Referring to Figure 22, an anchor handling vessel 270 receives the connection pendant 254 from the VTBM 252 and connects an insert wire 272 thereto. The anchor handling vessel 270 pays out the insert wire 272 as indicated by the arrows 274 and moves away from the VTBM 252 as indicated by the arrow 276.

As is shown in Figure 23, a tensioning chain 280 is inserted between the insert wire 272 and a pendant 282. The pendant 282 is in turn connected to a work wire 284. The work wire 284 is paid out as indicated by the arrow 286

while the anchor handling vessel 270 moves further away from the VTBM 282 as indicated by the arrow 288.

Referring to Figure 24, the anchor handling vessel 270 pays out the work wire 284 until it arrives at the location of the buoy 268. The anchor handling vessel 270 recovers the buoy 268 and secures the distal end of the mooring line 260 in a sharks jaws retainer. The buoy 268 is stored on the anchor handling vessel 270.

As is shown in Figures 25 and 26, the distal end of the mooring line 260 is connected to a clamping apparatus 290 constructed in accordance with the present invention. The work wire 284 is extended through the clamping apparatus 290. A line 292 is secured to the clamping apparatus 280 and is utilized to lower the clamping apparatus 290 from the anchor handling vessel 270. A remote operated vehicle (ROV) 294 is deployed from the anchor handling vessel 270 and is utilized to inspect and observe the clamping apparatus 290, the connection of the mooring line 260 thereto and the movement of the work wire 284 through the clamping apparatus 290 as the clamping apparatus 290 moves downwardly.

Referring to Figures 27 and 28, the anchor handling vessel recovers the work wire 284 through the clamping apparatus 290. The ROV 294 continues to monitor the connection between the line 292 and the clamping apparatus

290 and the movement of the work wire 294 through the clamping apparatus 290. The foregoing procedure continues until the chain section 280 is received in the clamping apparatus 290. At this point the pendant 282 has passed through the clamping apparatus 290. The ROV actuates the clamping apparatus 290 to engage the chain suction 280.

As is best shown in Figure 29, the anchor handling vessel next reverses course so that it moves in the direction indicated by the arrow 296. The line 292 is paid out until it becomes slack. The engine power of the anchor handling vessel 270 is applied to the chain 280 whereby the chain 280 is drawn through the clamping apparatus 290 until a predetermined tension is applied to the VTBM and to the mooring line 260. The clamping apparatus 290 clamps the mooring line 260 to the line extending from the VTBM 252 comprising the pendant 254, the insert line 272, and the chain 280.

The next step of the method is illustrated in Figure 30. The ROV 294 disconnects the line 292 from the clamping apparatus 290, and the line 292 is recovered onboard the anchor handling vessel 270. The pendant 282 is deployed from the anchor handling vessel 270 and the upper end thereof is secured in a sharks jaws retainer. The submersible buoy 268 is secured to the upper end of the pendant 282 while the work wire 284 remains secured to the

pendant 282 below the buoy 268. The pendant 282 is released from the sharks jaws retainer and the work wire 284 is utilized to lower the clamping apparatus 290, the upper end of the chain 280, the pendant 282, and the buoy 268. When the lowering operation is complete, the work wire 284 is disconnected from the pendant 282 by the ROV 294, whereupon the component parts are positioned as illustrated in Figure 31.

A method of offshore mooring 190 comprising a fifth embodiment of the invention is illustrated in Figure 32. In accordance with the fifth embodiment of the invention, a vessel to be moored (VTBM) 302 is moored at a mooring site 304 which is coincident with the illustration of the VTBM in full lines.

The VTBM 302 is initially positioned as indicated in dashed lines wherein the VTBM is somewhat displaced from the mooring site 304. With the VTBM situated at its displaced location, conventional mooring lines 306 are connected between anchoring points 307 and the VTBM 302. As will be appreciated by those skilled in the art, because the VTBM is situated at a location somewhat offset from the mooring site 304, sufficient slack is provided in the conventional mooring 306 to facilitate installation thereof.

After the conventional mooring lines 306 have been installed, the VTBM 302 is moved to the installation site 304. Thereafter, apparatus for offshore mooring 308 comprising the present invention are connected to the VTBM. The apparatus for offshore mooring 308 may comprise any of the embodiments disclosed herein and are adapted for activation by an anchor handling vessel. In this manner the anchor handling vessel is employed not only to apply predetermined tension to the apparatus for offshore mooring 308, but also to the conventional mooring lines 196.

Referring to Figure 33, the method of and apparatus for offshore mooring 310 comprising a sixth embodiment of the invention is illustrated. In accordance with the fourth embodiment of the invention, a vessel to be moored (VTBM) 312 is situated at a mooring site 314 which is coincident with the outline of the VTBM as illustrated in Figure 33. Conventional mooring lines 316 are connected to the VTBM. The conventional mooring lines 316 provide the VTBM with a predetermined mooring rating, for example, a ten year hurricane rating.

In accordance with the sixth embodiment of the invention, supplemental mooring systems 320 constructed in accordance with the present invention in addition to the conventional mooring lines 316. Each of the supplemental mooring systems 320 comprises a mooring line, a clamping

apparatus, and a pendant extending from the VTBM to the mooring apparatus. Either the mooring line or the pendant extends through the clamping apparatus to the distal end adapted for the engagement by a line extending from an anchor handling vessel. The anchor handling vessel is utilized to apply a predetermined tension to each of the supplemental mooring systems 320. In this manner the mooring rating for the VTBM 312 is substantially raised, for example, from a ten year hurricane rating to a fifty year hurricane rating.

It will therefore be understood that the method of and apparatus for offshore mooring comprising the present invention is adapted for mooring mobile offshore drilling units, floating production platforms, SPARs, and other apparatus at offshore venues without requiring the use of mooring winches on the apparatus to be moored. Because the mooring winches which have heretofore been required to effect mooring operations at offshore venues are extremely expensive, the use of the method and apparatus of the present invention results in substantial cost savings.

Although preferred embodiments of the invention have been illustrated in the accompanying drawings and described in the foregoing Detailed Description, it will be understood that the invention is not limited to the embodiments disclosed, but is capable of numerous

rearrangements, modifications, and substitutions of parts and elements without departing from the spirit of the invention.